SAE J 1757 Standard Metrology for Vehicular Displays

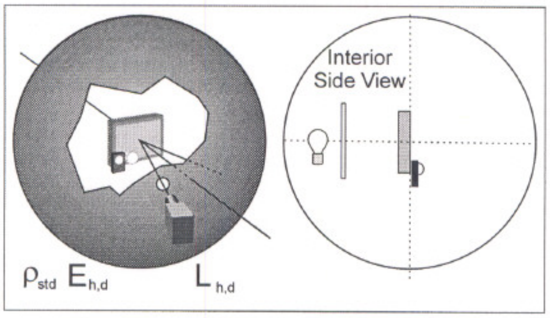
This is a report to the committee regarding reflection measurements that impact the current draft standard.

PLEASE NOTE: DISCLAIMER

The data presented here are for illustration purposes only and are provided in response to the needs of the SAE committee. They are not to be regarded as either accurate or precise results. Their release to the SAE and to the display industry in general are for discussion purposes only to assist in the clarification of our understanding and perception of reflection metrology as applied to displays. Reflection measurement results are, in general, dependent upon the samples employed and very dependent upon the precise geometry of the apparatus, all of which is not discussed in any detail in this presentation. The diffuse reflectance measurements have a relative expanded uncertainty with a coverage factor of two of 2 %. The rest of the measurements are insufficiently characterized to permit an uncertainty analysis as they were not intended to provide precise measurements; they were intended to characterize trends and illustrate phenomena and measurement problems. Future work will provide more details.

Diffuse Reflectance Results

- **Directed Hemispherical Reflectance ($\beta_{d/8} = \rho_{8/d}$)**



	Blk Gls	STD WHT	BLK	D01	B2	SAEH	SAES
$\rho =$	0.0481	0.980	0.0403	0.0514	0.107	0.0573	0.0153

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This is a measurement of the diffuse reflectance (or reflectance) ρ of these displays and surfaces according to the model relating the luminance L (cd/m^2) and the illuminance E (lx):

$$\rho = \pi L / E .$$

Here the luminance measurement is made 8° from the display's normal, and the source is a uniform diffuse illuminator. A few more details of the samples are available in slide #6.

•SAEH display exhibits primarily a haze component arising from a microstructure over the front surface—what many call an anti-glare (AG) surface. It destroys the distinct virtual image associated with a specular display by diffusing it (making it fuzzy).

•SAES display exhibits a specular component with a horizontal haze spike. However because it has an anti-reflecting coating on the front surface the overall reflection is low.

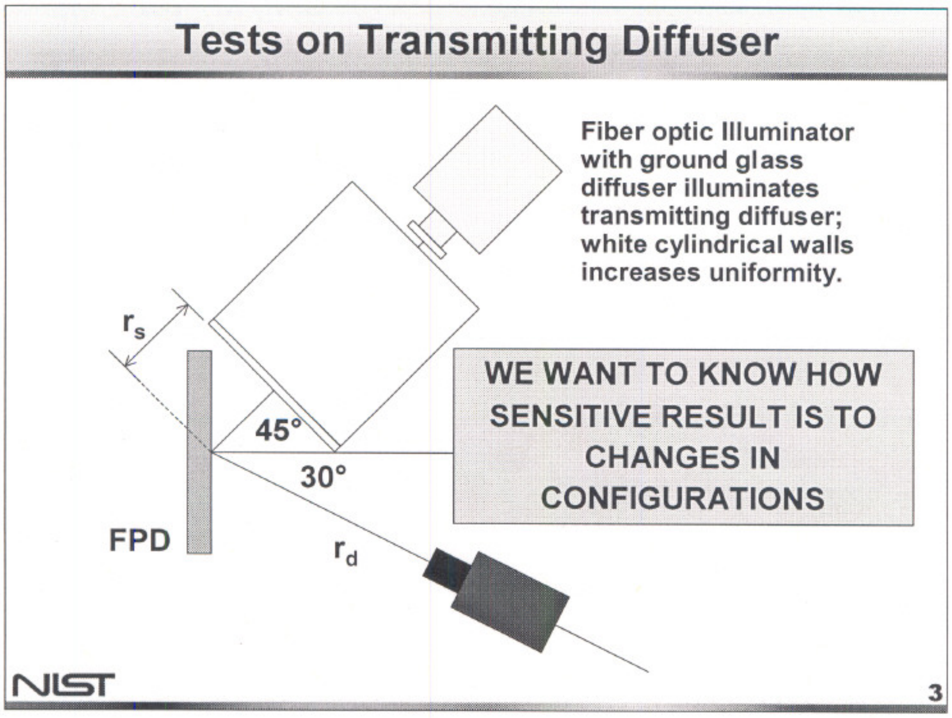
•STD WHT: A white diffuse standard, pressed polytetrafluoroethylene.

•BlkGls: Black glass RG-1000 glass filter (visible blocking).

•BLK: Black matte sample, black vinyl plastic with a matte surface.

•D01: Sample D01 is a glass used in FPD manufacturing with painted black back. It exhibits a weak specular component, mostly a haze component (producing the AG look), and trivial Lambertian component.

•B2: Sample B2 is an AG glass using in picture framing, matte black vinyl behind.It exhibits a weak specular component, mostly a haze component (producing the AG look), and a noticeable Lambertian component. It looks somewhat like a CRT (cathode ray tube) display surface.



A transmitting diffuser is made from a white plastic disk that subtends from the normal of the display to beyond its edge. Both sides are sanded with 240 grit emery paper to eliminate any residual transparency whereby a distinct image of the source can be seen through the plastic. The white walls of the cylinder serve to make the surface a more uniform illuminator. A ground glass diffuser in front of the fiber-optic illuminator serves to further diffuse the illumination to make as uniform transmitting diffuser as possible (the source is used without the fiber optics—the unit is used as a strong directed tungsten-halogen light source).

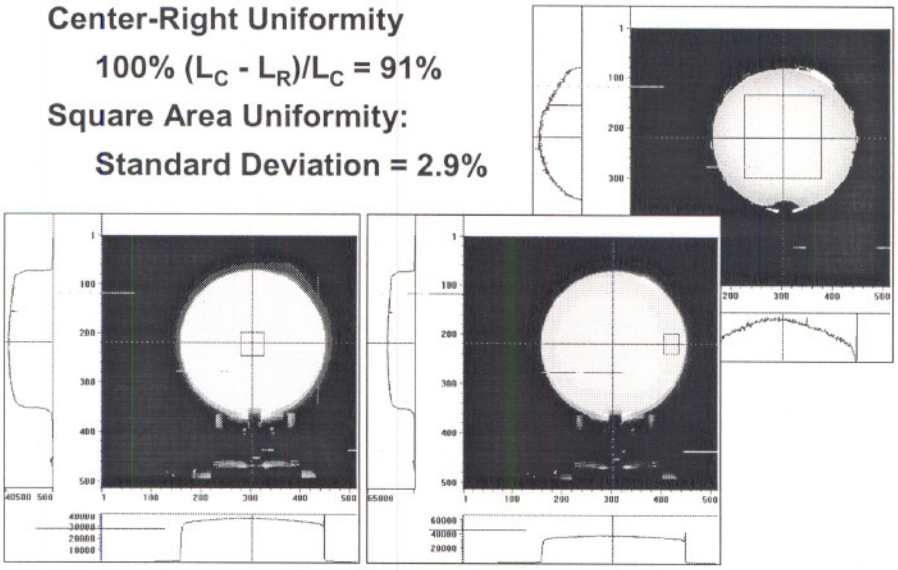
Uniformity of Source

Center-Right Uniformity

100% $(L_C - L_R)/L_C$ = 91%

Square Area Uniformity:

Standard Deviation = 2.9%



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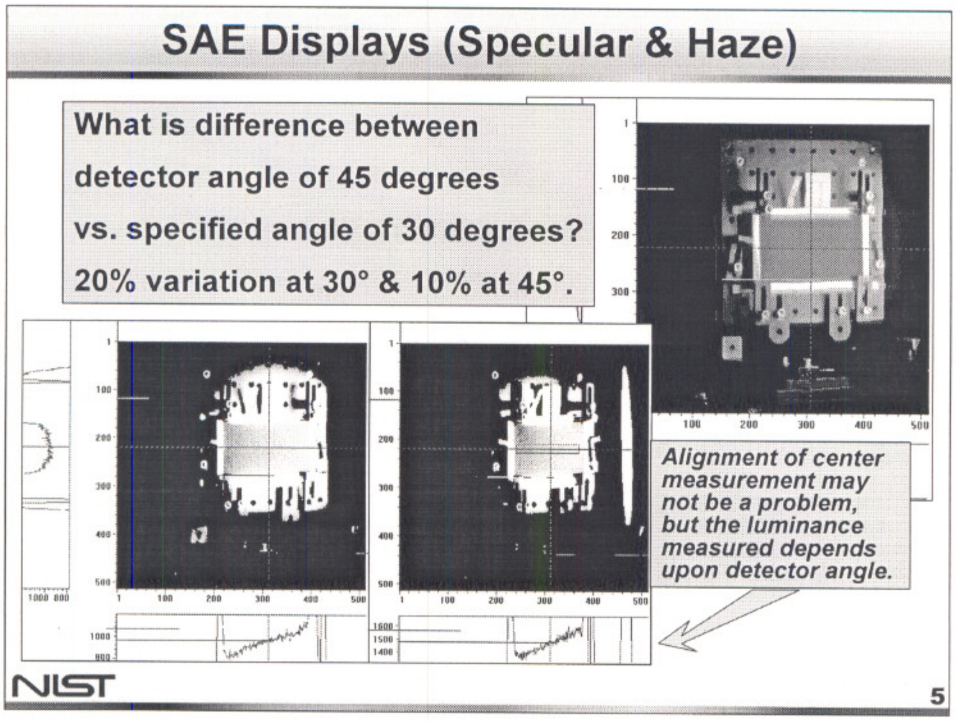
We compare the center-to-right uniformity of the source (a worst case uniformity) with the uniformity obtained by an average over a square covering much of the surface.

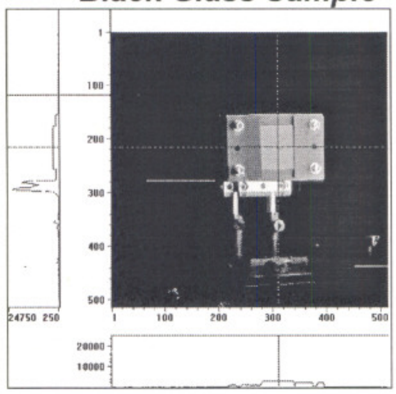


There is concern that using a detector angle of 30° provides a substantially less suitable configuration than if the detector angle were the same as the source angle of 45°. Here the luminance variation is measured across the width of the screen (narrow rectangle in center picture) for detector angles of 30° and 45°. The luminance variation at 45° was 10 % whereas at 30° it was 20 %. Because the luminance will be measured at screen center, there is little risk that most technicians will observe any problems from using the 30° detector angle that they would not encounter at 45°. For measuring the center of the screen we would expect only 1 % or 2 % deviations for lateral misalignments arising from sloppy techniques. However, noteworthy is the difference in center measurements for these two angles: The display at 30° measures approximately 960 counts whereas at 45° the center measures approximately 1480 counts (counts from the charge-coupled-device [CCD] camera are proportional to the luminance). **This illustrates that the measurement result depends dramatically upon the angular alignment of the source and detector.** The sensitivity exhibited here is approximately 3.6 % per degree of the measurement taken at 30°. That is, if the relative alignment of source and detector differ by 5° from the specified 30° and 45° respectively, we can expect an 18 % change in the measurement result.

Other Samples Used

- In addition to two SAE displays: (haze [SAEH] and specular with AR coating[SAES]) ...

Black Glass Sample



- White diffuse standard
- Black glass (specular)
- Black matte (no specular component)
- Sample D01 (FPD front glass with back painted black, dark, all three components present, but Lambertian is very small)
- Sample B2 (Similar to CRT "look" with strong front diffusion treatment and grayish look, all three components present and nontrivial)

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Two displays are used along with several sample materials. The two SAE displays have been measured by members of this committee in the past. The SAEH display exhibits primarily a haze component (an anti-glare [AG] front surface from the surface microstructure), no specular component, and a trivial Lambertian component. The SAES display exhibits a specular component producing a distinct image of the source, a spiked haze component in the horizontal direction that horizontally smears the specular image, and a trivial Lambertian component. The SAES display also has a very nice anti-reflection [AR] coating on its front surface.

The white diffuse standard is pressed polytetrafluoroethylene sanded under running water with a combined circular-linear motion using 240 grit emery paper.

The black glass is RG-1000 glass filter (visible blocking).

The black matte sample is black vinyl plastic with a matte surface. It has no specular component and is mostly Lambertian.

Sample D01 is a glass used in FPD manufacturing with the back painted with a latex black paint.

Sample B2 is an AG glass using in picture framing with a matte black vinyl plastic material placed behind it (not bonded to it). It looks very much like a typical CRT computer monitor that has a medium AG front surface etched on the glass.

Sensitivity to Distance from Source, r_s

DISTANCE = 102 mm								
E (lx)		**Blk Gls**	**WSTD**	**BLK**	**D01**	**B2**	**SAEH**	**SAES**
866	Lsample	40.0	309	19.3	39.8	82.1	46.7	11.8
LumFac	$\beta = \pi$ L/E =	0.145	1.122	0.0701	0.144	0.298	0.169	0.0428
If we were ignorant and assumed a specular only model...								
	ζ = L/Ls	0.0469	0.363	0.0227	0.0467	0.0965	0.0548	0.0139
What is relationship between reflectance and luminance-factor measurements?								
Previously took data using diffuse ambient source on all these samples:								
Reflectance	ρ =	0.0481	0.980	0.0403	0.0514	0.107	0.0573	0.0153
	Ratio β/ρ =	**3.02**	1.14	1.74	**2.81**	**2.79**	**2.95**	**2.80**
		So... for haze and specular displays...						
			this factor of 2.8 to 3 looks like it will work (maybe...).					
				BUT... NOT for Lambertian-like surfaces.				
DISTANCE = 71 mm								
E (lx)		**Blk Gls**	**WSTD**	**BLK**	**D01**	**B2**	**SAEH**	**SAES**
1170		40.4	416	23.0	40.7	85.3	47.9	12.5
LumFac	$\beta = \pi$ L/E =	0.108	1.118	0.0617	0.109	0.229	0.129	0.0336
Error from previous β		**-28.8%**	**-0.4%**	**-12.6%**	**-27.5%**	**-26.2%**	**-27.3%**	**-24.1%**
	∴ ***Thus, for most displays, there is a sensitivity to source distance.***							
If we were ignorant and assumed a specular only model...								
	ζ = L/Ls	0.0474	0.489	0.0270	0.0478	0.100	0.0562	0.0147
Error from previous ζ		-1.0%	-29.5%	-17.4%	-2.4%	-3.8%	-2.6%	-5.8%

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The main conclusion is in dark red, that there is a sensitivity of the result to the configuration, in particular, there is a sensitivity to the distance of the transmitting-diffuser source from the display, and previously we saw that the source-display-detector angular alignment was important. The apparent reflectivity (luminance factor defined by

$$\beta = \pi L / E$$

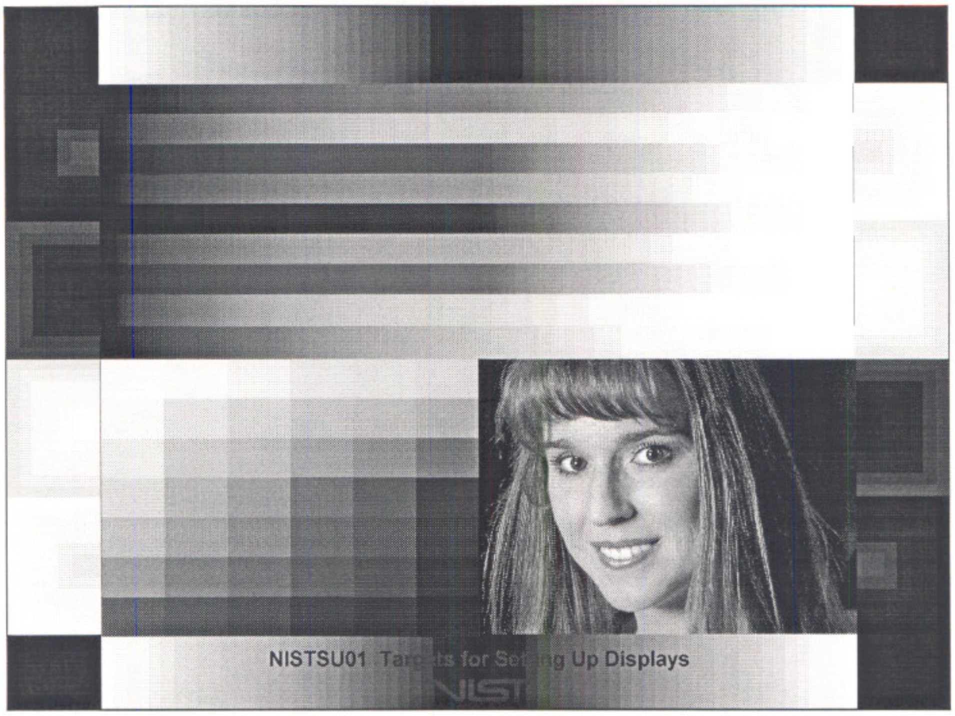
for the specified geometry of the source, detector, and sample; here L is the luminance and E is the illuminance) went down as the source was moved closer to the display. We reduced the distance by about 30% and the reflection went down by 26% or so. **Thus, the transmitting-diffuser method is NOT robust in that the measurement result is sensitive to changes in the apparatus that will likely be encountered in practice.** Both the angular alignment and the source distance can affect the result significantly.

The bright red text demonstrates that there is a factor of, roughly, three between the reflectance (diffuse reflectance) and the luminance factor obtained using the transmitting-diffuser method, but only for displays that have a very low or ignorable Lambertian component. As the display approaches the qualities of a Lambertian reflector, the ratio moves from three toward one.

The green text shows what we would obtain if we ignorantly assumed a specular reflection model for all the surfaces where the observed luminance L is proportional to the source luminance L_s

$$L = \zeta L_s .$$

This is strictly correct only for the black glass as the 1 % error in green would indicate.



This slide serves the purpose of seeing how well a projector will render detail in blacks and whites. Some older projection systems tend to wash out the whites and fade the dark grays to black. This can represent a serious problem if a range of color and gray scales are used in the presentation of the material. The complete set is available from

www.fpdl.nist.gov

or

www.fpd.nist.gov

on the Patterns page.